Review of ATD Program

II. Current Baseline

Changes from one year ago

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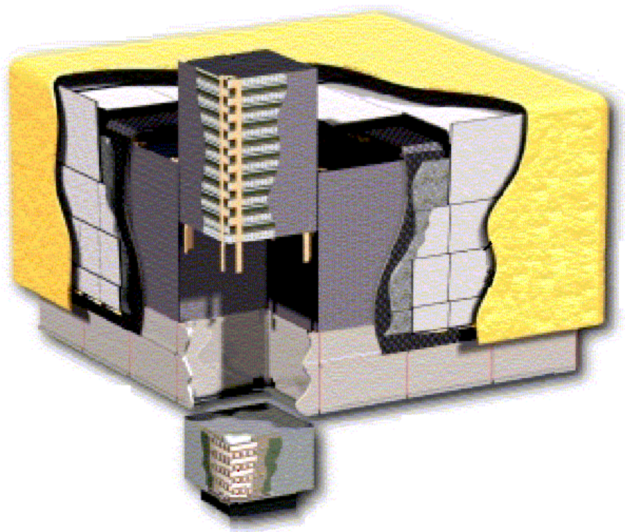
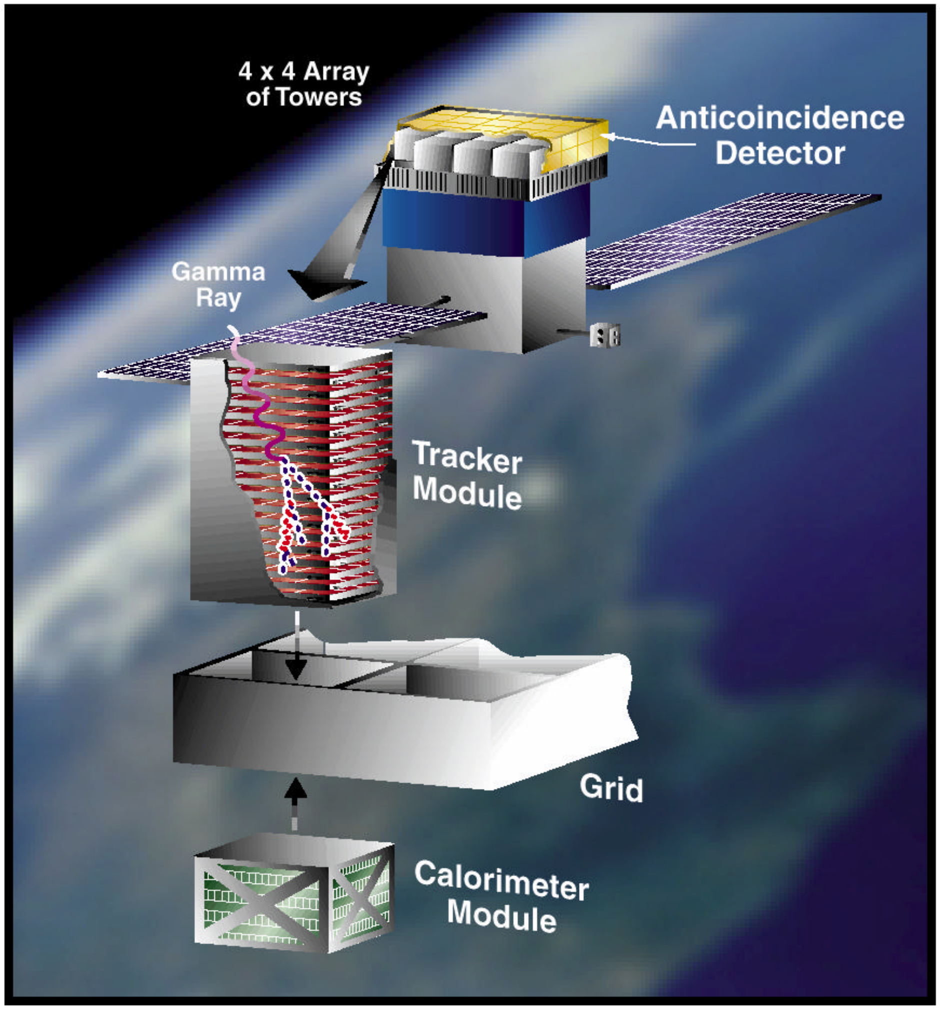
20 March 2000

Results of hard work by many people.
Technical foundation: Bill Atwood



Instrument Basics

- <u>4x4 array of identical towers</u>
  Advantages of modular design.
- <u>Precision Si-strip Tracker (TKR)</u>
  Detectors and converters arranged in 18 XY tracking planes. Measure the photon direction.
- <u>Hodoscopic CsI Calorimeter(CAL)</u>
  Segmented array of CsI(Tl) crystals. Measure the photon energy.
- <u>Segmented Anticoincidence Detector (ACD)</u>
  First step in reducing the large background of charged cosmic rays. Segmentation removes self-veto effects at high energy.
- <u>Data Acquisition (DAQ) System</u>
  Includes flexible, highly-efficient, multi-level trigger.



<u>Systems work together to identify and measure the flux of cosmic gamma rays with energy 20 MeV - >300 GeV.</u>

Key Science Questions

- What are the mechanisms of particle acceleration in the Universe?
- What are the origins and mechanisms of Gamma-Ray Bursts and other transients?
- What are the unidentified EGRET sources?
- What are the distributions of mass and cosmic rays in the Galaxy and nearby galaxies?
- How can high energy gamma rays be used to probe the early Universe?
- What is the nature of dark matter?

Evolution of Design

- **Overall footprint has been ~fixed. (small changes)**
- **Improved understanding of system has led to two major developments:**
  - 5x5 → 4x4
  - Uniform radiator → Distributed radiator in two sections: thinner “Front” + thicker “Back” (“SuperGLAST”)
- **Yields excellent science performance (and it should get better as the reconstruction algorithms improve)**

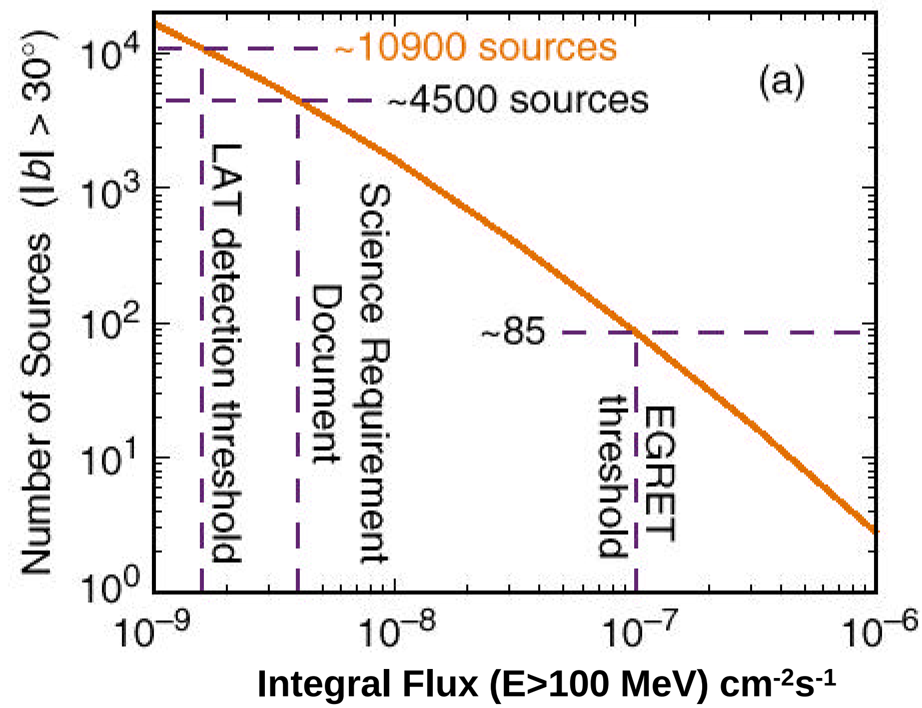
2-yr high latitude point source sensitivity (E>100 MeV):

1.6×10^{-9} cm^{-2}s^{-1}

SRD requirement:

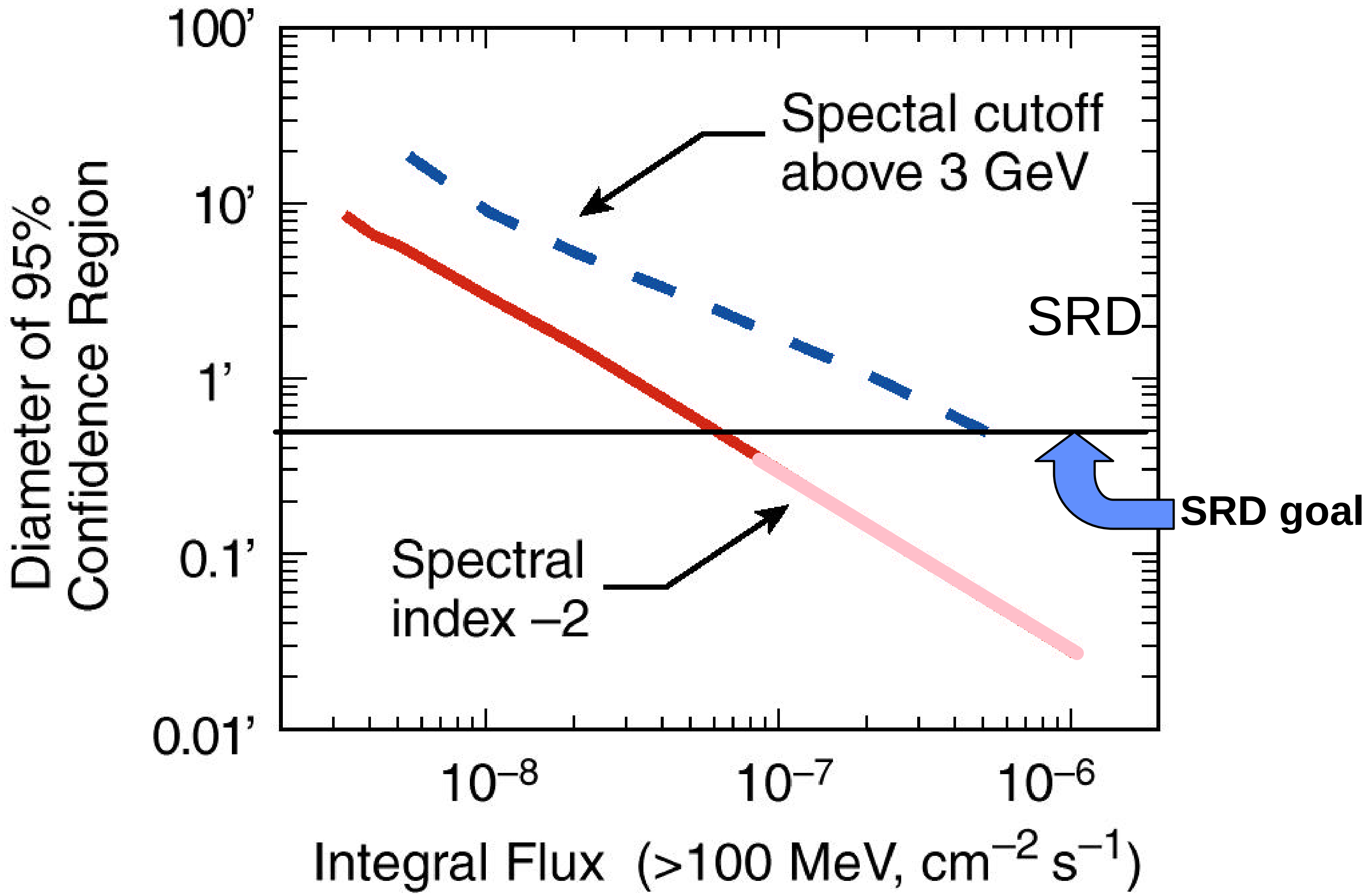
4×10^{-9} cm^{-2}s^{-1},

goal $<2\times10^{-9}$ cm^{-2}s^{-1}



There shall be discoveries

Source Localizations



SRD, IRD, ATD R&D

Quantity	REQUIREMENT	GOAL
Point source sensitivity (>100 MeV) cm^{-2} s^{-1}	$4x10^{-9}$	$<2x10^{-9}$
Source localization	1-5 arcmin	30 arcsec – 5 arcmin
Peak Effective Area	8000 cm^2	>10,000 cm^2
Single photon angular resolution (68%, on-axis)	<3.5 deg (100 MeV) <0.15 deg (E>10 GeV)	<2 deg (100 MeV) <0.1 deg (E>10 GeV)
Single photon angular resolution (95%, on-axis)	$< 3x\theta_{68}$	$2x\theta_{68}$
Single photon angular resolution (off-axis at FWHM c FOV)	<1.7 times on-axis	<1.5 times on-axis
***Field of view (FOV)**	2 sr	>3 sr

Design studies focused on:
- Effective area
- 68% containment space angle
- 95% containment space angle
- Field of view
- Energy resolution
- Background rejection

while minding:
- Power
- Mass
- Size
- Downlink bandwidth
- Environment

+ cost and schedule!

NOTE: for science, the performance parameters combine. For example, the point source sensitivity $\alpha\ [Aeff]^{1/2}/\theta_{68}$

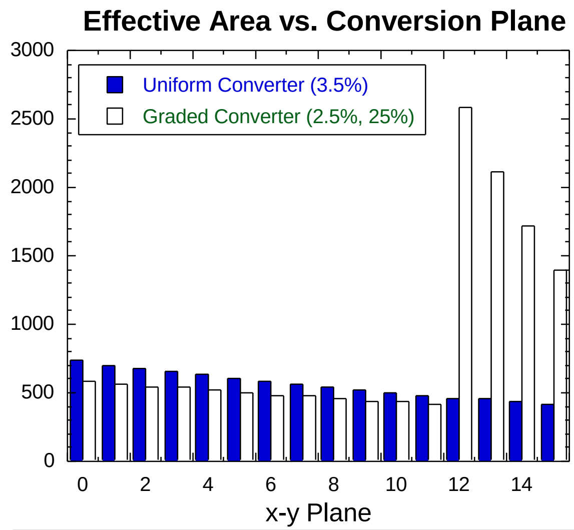
4x4 GLAST

- Size of tower driven by SSD ladder length (total strip length), which is driven by noise requirements (effects of input capacitance, EMI, etc.), which is driven by the L1 trigger requirements (occ < 1×10^{-4}).
- Earlier design very conservative: 7x7 array of smaller towers. Early positive experience with low-power custom electronics led us to a 5x5 array of 32 cm towers with 16 XY detector planes in basic Option period.
- **Further experience with the electronics and real ladders, and the availability of 6" wafer technology => 4x4 array of 40 cm towers.**
  - Preserves the many benefits of modularity
  - Fewer SSD's required (9,216 instead of 20,000) and decrease of fractional dead area.
  - Fewer channels, lower power per plane => can add planes and still save significantly on power. Stack is now 18 XY detector planes.
  - More favorable I&T schedule
- **Implications for CAL**: requires 40 cm CsI logs – available. Number of logs per tower 80 -> 96, but there are fewer towers: total # logs in system drops from 2000 to 1536 (30% reduction) while preserving imaging capabilities.
- **Implications for ACD**: ~none. Maintain 5x5 array of tiles to cover inter-tower cracks with tiles.

Radiator Optimization

- **Recall, 5x5 GLAST had 14 layers of 3.5% r.l. converters. Only ~50% of the photon flux would convert in the TKR. Strong desire to measure more of the flux, particularly at high energy. Most approaches involved the calorimeter, using imaging.**
- **Atwood (Paris, Dec. 1998):** ***thin*** the radiator in the first layers, to improve the low energy PSF, and have a few layers in back with ***thick*** (~20% r.l. each) radiators to target more of the high energy (> few GeV) flux.
- **Resulting design:** ***FRONT:*** 12 layers of 2.5% r.l. converter

BACK: 4 layers of 25% r.l. converter followed by 2 “blank” layers



•Jump in Aeff (from ~9000 cm^2 to ~12,500 cm^2) with good PSF and improved aspect ratio for back converters.

• Approximately same contributions to the point source sensitivity from Front and Back sections, in a complementary manner: Front has better PSF, Back has more photons.

• Work ongoing to finalize radiator thicknesses & pitch.

TKR now has 1.5 r.l. of material. Reduce CAL thickness to 8.5 r.l. to maintain 10 r.l. total.
(May think of Back section of TKR as a “trackorimeter”.)

Summary of results of optimizations

Design	Pre Base	Post Option 1	Issue	Justification
Instrument Linear Dimension	161.5cm	150cm	Weight, Clearance	Increased Gamma Conversion
# of Towers	5x5	4x4	Noise in Tracker	Improved ASIC
Size of Tray	32cmx32cm	38cmx38cm	Noise in Tracker	Improved ASIC
# of x-y layers	16	18	Cost of Si, Power	Lower Cost of Si
Radiation Length per x-y layer	Uniform 3.5%	Graded: 2.5%, 25%	Effective Area	Instrument Optimization
Total Tracker Radiation Length	0.71	1.5	Effective Area	Instrument Optimization
Fraction of Photons converted in Tracker	48%	76%	Effective Area	Instrument Optimization
A_{eff} [cm^2] at 10GeV	9,000	12,500	Converter mass	Instrument Optimization
# of Si wafers	20,000	9,216	Cost, Schedule	Availability of 6” tech.
Size of Si sensors	6.4cm× 6.4cm	9.2cm×9.2cm	Cost, Dead Space	Availability of 6” tech.
Depth of Calorimeter (R.L.)	9.5	8.5	Instrument Mass	Shift Mass into tracker
# of CsI logs/Tower	80	96	Tower Size	Larger Towers, resulting in 23% **fewer** logs in total in the instrument.
Size of CsI log	3.0cmx2.3cmx31cm	2.8x2.0x35.2	Maximum Length	~40cm logs available
# of ACD tiles	86	145	Self-veto due to back-splash	Beam test, simulations
Coverage of tiles	Align with towers	Cover tower cracks	High rejection of C.R.	Simulations
DAQ Organization	Separate TEM cards for TKR and CAL	Same TEM boards for TKR and CAL	Cost/Schedule savings	

Background Rejection

- **Reminder: analysis done thus far for two main reasons:**
  - (1) A reasonable way to quote our effective area.
  - (2) A proof of principle, demonstration of the power of the instrument design.

Don’t expect this to be the final background analysis!

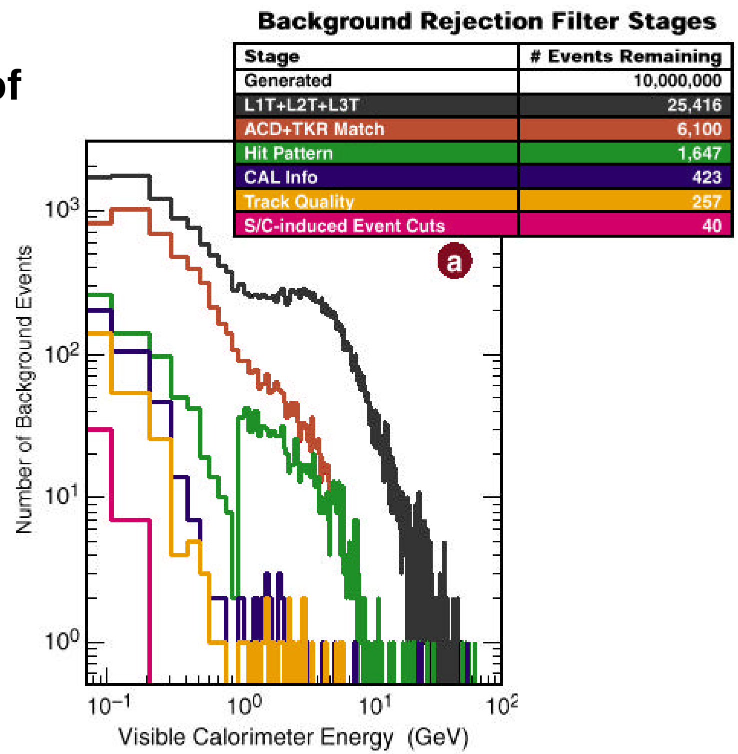
Some science topics may require less stringent background rejections than others.
Don’t expect the simulations of the background to be accurate to this level.

Much progress over the past year:

- **Evolving understanding of the flux, new sources of backgrounds included. Right now:**

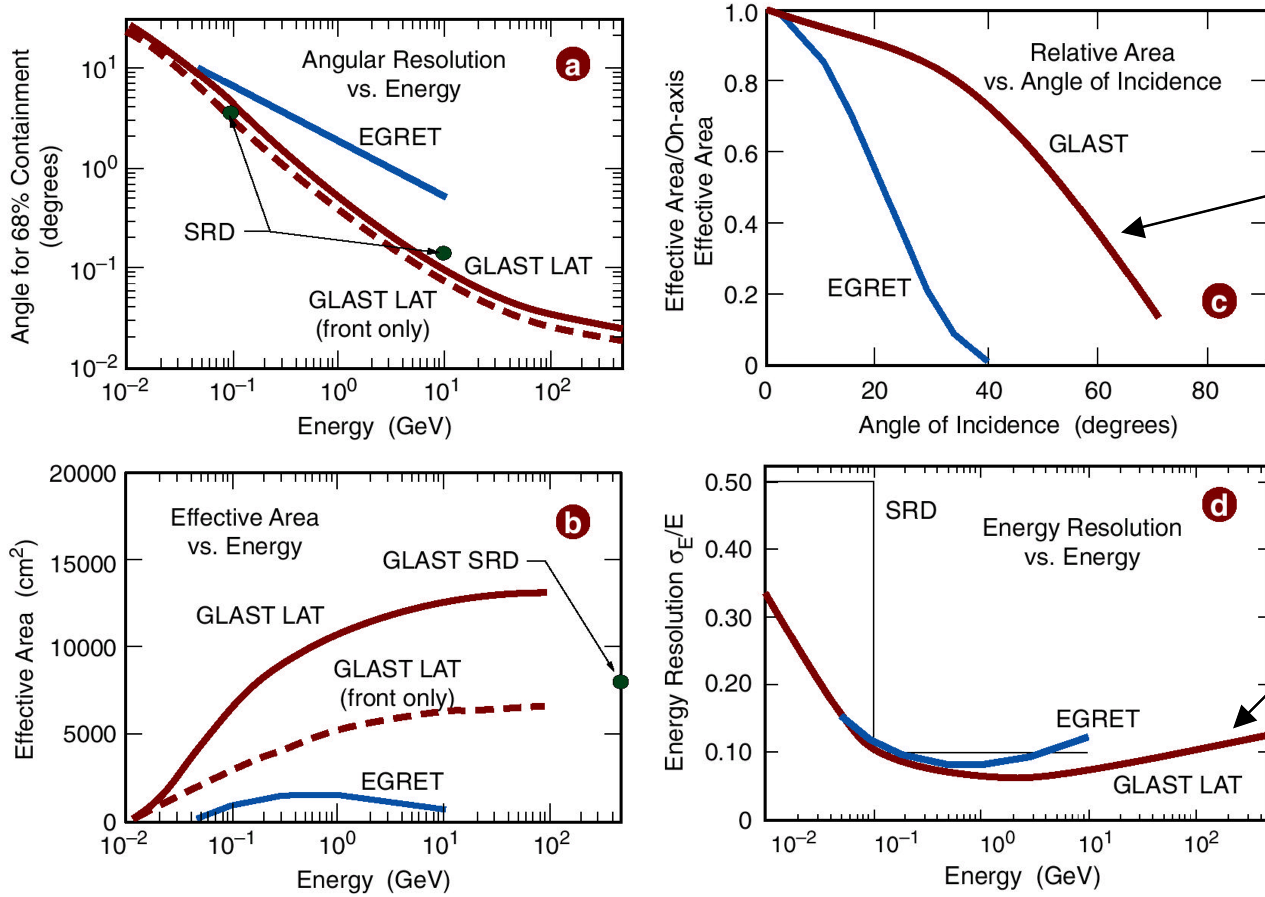
Source	% rate	Avg L1T Rate [Hz]
Chime	36	2019
galbedo	4	196
Electron	1	30
Albedo p	59	3224
TOTAL		**5470**

- **Important incremental source of background: CR events whose primary interaction is in the S/C. Imaging CAL is the key to reducing this bkgd.**
- **Work is ongoing.**



Performance Plots

(after all background rejection cuts)



FOV w/ energy measurement due to favorable aspect ratio

Effects of longitudinal shower profiling

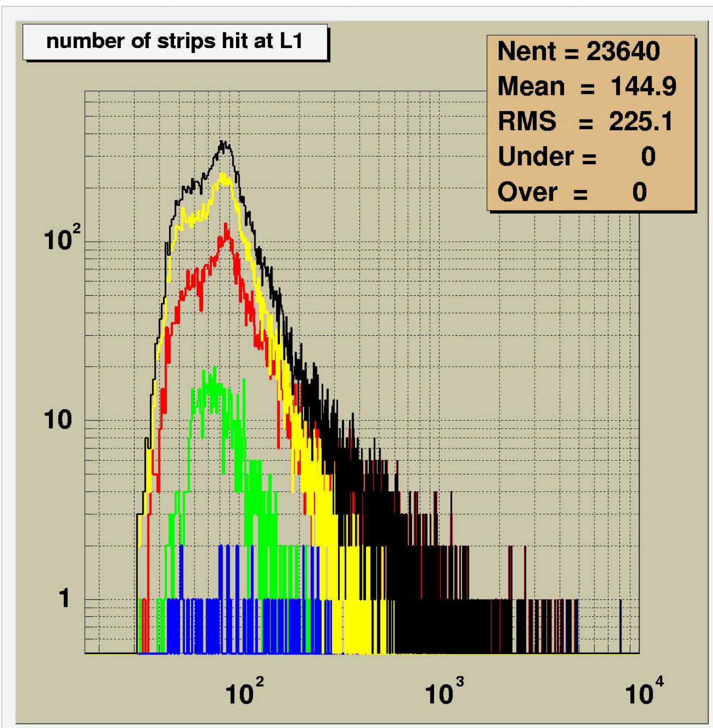
Derived performance parameter: high-latitude point source sensitivity (E>100 MeV), 2 year all-sky survey: 1.6x10^{-9} cm^{-2} s^{-1}, a factor > 50 better than EGRET's (~1x10^{-7} cm^{-2}s^{-1}).

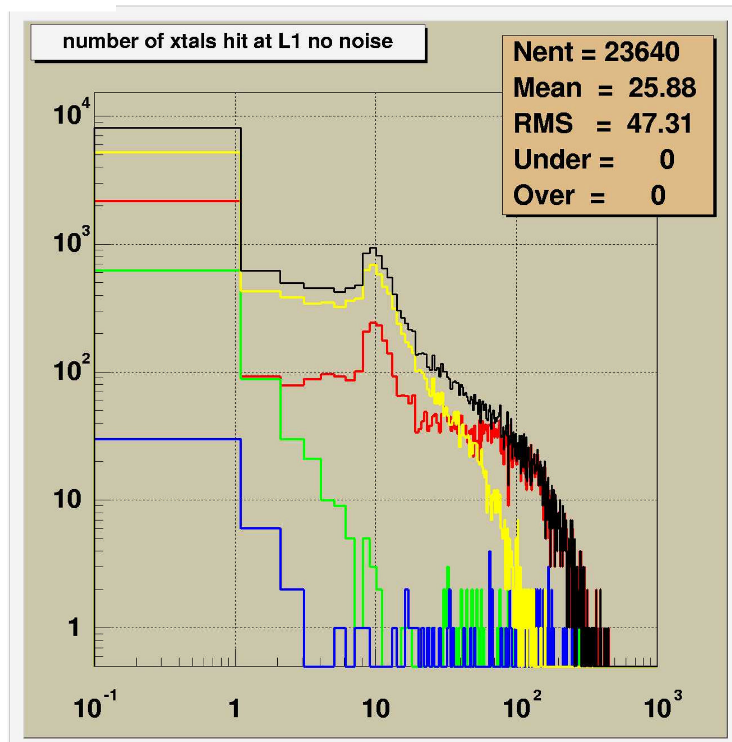
Further work on internal data volume

Current calculations of data volume for TKR and CAL at L1T

source	mean #strips	frac total TKR data
chime	213	0.54
gamma albedo	105	0.03
electron	657	0.03
albedo p	100	0.41
TOTAL	145.0	

source	frac total rate	rate [Hz]	mean #xtals	frac total CAL data
chime	0.37	2019	52.3	0.75
gamma albedo	0.04	196	4.2	0.01
electron	0.01	30	86	0.02
albedo p	0.59	3224	10.1	0.23
TOTAL		5470	25.9	





all background
p albedo
Chime
g albedo
electrons

Orbit-average
(many details, caveats)

This is not the science telemetry!!

Power and Mass summary

Component		Mass + Reserve (kg)		Power (W) + Reserve		# Parts & Size per Part		Status Class	Status Stage
Total Instrument:		**2558+377**	**15%**	**518 + 121**	**23%**	**1**	**1.733^2 x 1.055 m**		
Grid		143 + 50	35%			1	1.546^2 x 0.308 m	1	Bid
Thermal system (incl. radiators)		50 + 25	50%					1	Bid
Thermal Blanket & Shield		27 + 8	30%					2	Bid
TKR	Mechanical Structures	191 + 67	35%			16	0.381^2 x 0.619 m	1	Bid
TKR	Silicon Strip Detectors	73 + 2	3%			9216	92.2^2 x 0.4 mm	3	CoDR
TKR	Pb Converters (front)	40 + 1	3%			3072	90.6^2 x 0.14 mm	3	CoDR
TKR	Pb Converters (back)	133 + 4	3%			1024	90.6^2 x 1.4 mm	3	CoDR
TKR	Electronics, Cabling, misc.	84 + 25	30%	273 + 35	13%			2,3	Bid
CAL	Mechanical Structures	162 + 49	30%			16		1	CoDR
CAL	Cesium Iodide Crystals	1338 + 27	2%			1536	35.1 x 2.8 x 2.0 cm	3	Bid
CAL	Electronics & Cabling	32 + 16	50%	118 + 16	13%		0.374^2 x 0.239 m	1,3	Bid
CAL	Other (wrapping, etc.)	18 + 9	50%					1	Bid
ACD	Mechanical Structures	51 + 18	35%			1	1.667^2 x 0.757 m	1	Bid
ACD	Scintillators	85 + 17	20%			145	Varies (1 cm thick)	2	CoDR
ACD	PMT, HV supplies, cabling	24 + 12	50%	incl. in DAQ				1	Bid
ACD	Fibers, wrapping, etc.	15 + 7	50%					1	Bid
DAQ	TEM modules	32 + 10	30%	88 + 35	40%	16	28^2 x 8 cm	2	Bid
DAQ	SIU modules	15 + 7	50%	10 + 9	90%	2	28^2 x 10 cm	1	Bid
DAQ	ACD readout modules	5 + 3	50%	29 + 26	90%	2	28^2 x 10 cm	1	Bid
DAQ	Harness	40 + 20	50%					1	Bid
Margin w.r.t. SC-SI IRD:		65 kg		11 W					

Based on ANSI/AIAA G-020-1992 "Guide for Estimating and Budgeting Weight and Power Contingencies for Spacecraft Systems"

- Majority of mass is "simple"
- 37% cont. on "engineering" mass + 65 kg additional reserve wrt IRD.
- Avg: 15% mass reserve.

- Avg: 23% power reserve plus 11 W additional reserve wrt IRD.

Revised mass audit underway.

Power next.

Independent reviews

Subsystem designs and critical technology development decisions are reviewed by independent panels that include members outside of the collaboration. During Option 1, there were reviews of the ACD, DAQ and Software.

System	Date of Review	Members of Review Team
Silicon Detectors	June 1997	Carl Haber (LBL) John Matthews (U. of New Mexico) Nobu Unno (KEK, Japan) Phil Allport (Liverpool Univ, U.K.) (H. Sadrozinski (UCSC), secretary)
Tracker Front-end Electronics	November 1997	chair: M. Breidenbach (SLAC) Oren Milgrome (LBL) Ned Spencer (UCSC) James Wallace (Stanford Univ.) (W. Atwood (SLAC/UCSC) & H. Sadrozinski (UCSC), secretaries)
Calorimeter Electronics	June 1998	chair: Bill Atwood (SLAC/UCSC) David Dorfan (UCSC) Chuck Britton (Oak Ridge NL) Jim Ampe (NRL) Bob Baker (GSFC) Oren Milgrome (LBL) (Scott Williams (Stanford Univ.), secretary)
Anti-coincidence Shield	January 1999	chair: Hartmut Sadrozinski (UCSC) Marty Breidenbach (SLAC) Gary Godfrey (SLAC) Eric Ponslet (Hytec Inc) Bob Baker (GSFC) John Mitchell (GSFC) Jack Tueller (GSFC) Dick Kroeger (NRL) (Scott Williams (Stanford Univ.), secretary)
Data Acquisition System	April 1999	Chair: Steve Ritz (GSFC) Gunther Haller (SLAC) Terry Schalk (UCSC) Rodger Cliff (LMATC) Alan Ross (NRL/NPS) Gaylord Green (Stanford Univ.) Scott Williams (Stanford Univ.), secretary
Software	June 1999	Chair: Neil Johnson (NRL) Richard Dubois (SLAC) Keith Goetz (University Minnesota) Bob Jacobsen (UC Berkeley) Byron Leas (NRL) Tom McGlynn (GSFC) Jim Russell (SLAC) Terry Schalk (UCSC) Scott Williams (Stanford Univ.), secretary

Looking forward to…